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Socioeconomic status and end-stage renal disease in the United States

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Socioeconomic status and end-stage renal disease in the United States. The incidence of treated end-stage renal disease (ESRD) varies markedly according to age, race, sex, and geographic characteristics of the population. We asked whether some of the variability in the incidence of treated ESRD (t-ESRD) was associated with differences in socioeconomic status and whether socioeconomic status could explain some of the effects of race on t-ESRD incidence. Demographic characteristics of incident cases of t-ESRD from the years 1983 to 1988 were obtained from the U.S. Renal Data System, which registers most treated cases of ESRD. The average race specific, per capita income of the county of residence, as determined from the Bureau of Health Professions Area Resource File, was used as a surrogate measure of socioeconomic status. The incidence of t-ESRD for individuals <60 years of age was modeled as a log-linear function of socioeconomic and demographic factors, including age, sex, the urban fraction of the county of residence, and the census geographic region. For both Whites and Blacks, the incidence of t-ESRD was higher for males and older age groups, as expected. In general, the incidence of t-ESRD was inversely related to income level. For Whites, the relative risk was 1.21 for income of $0 to 10,000, 1.11 for $10,000 to 15,000, 1.00 for $15,000 to 20,000 (reference), 0.89 for $20,000 to 25,000, and 0.77 for income >$25,000. For Blacks, the relative risk was 1.10 for income of $0 to 10,000, 1.20 for $10,000 to 15,000, 1.00 for $15,000 to 20,000 (reference), 0.81 for $20,000 to 25,000, and 0.69 for income > $25,000. At the lowest income level, the incidence of t-ESRD was lower than would be projected by a linear model for Blacks. The high absolute incidence of t-ESRD among Blacks was only partially explained by lower socioeconomic status. The incidence of t-ESRD varies by approximately 40 to 50% over the range of average per capita income levels but average county income does not fully explain the effects of race, sex, or age.

The incidence of treated end-stage renal disease (t-ESRD) in the United States varies dramatically according to demographic factors such as race, age, sex, and place of residence [1–5]. Variability in t-ESRD incidence may reflect differences in the frequency and natural history of the diseases that lead to kidney failure as well as genetic, environmental, social, and medical practice factors. In recent years, the incidence of t-ESRD has been increasing at an age-, race-, and sex-adjusted rate of 7.2% annually; faster growth has occurred in selected subgroups [1]. An improved understanding of factors that are associated with variability in the incidence of t-ESRD may help to identify strategies to control the alarming growth in both the number of new patients with kidney failure and the cost of their treatment.

Socioeconomic status is a potential determinant of several factors that may influence the expression of kidney disease, including access to preventive health care, access to dialysis treatment, and exposure to putative nephrotoxins. Socioeconomic status is also associated with diseases that lead to kidney failure such as hypertension [6–8] and diabetes [9, 10]. Furthermore, Blacks as a group have a higher incidence of t-ESRD and a lower socioeconomic status than Whites. We tested the hypothesis that t-ESRD is associated with socioeconomic status, independent of the known associations with race, age, and sex. We also asked whether the higher incidence of t-ESRD among blacks could be explained by differences in socioeconomic status. These questions were approached by linking information from the United States Renal Data System (USRDS) and the Bureau of Health Professions Area Resource File (ARF). The USRDS maintains a registry of most cases of t-ESRD in the United States. The ARF database contains socioeconomic and demographic characteristics of all counties in the United States.

Methods

The USRDS database was used to generate cumulative age-, race-, and sex-specific incidence counts for each county over the years 1983 to 1988 [1]. The primary source of data for the USRDS is the Medicare Medical Evidence form that is filed for each new patient receiving renal replacement therapy. USRDS includes more than 90% of t-ESRD patients in the United States [1]. Incidence rates over the six-year study period were calculated based on 1985 population estimates as projected from the 1980 census. The ARF database [11] provided race-specific, average per capita income and the fraction of the total county population living in an urban setting (urban fraction) for counties as determined from the U.S. Census. The urban fraction was defined according to the 1980 Census as the fraction of the county population "living in urbanized areas and in places of 2500 or more inhabitants outside urbanized areas" [12]. Non-urban residents comprise the rural population of the county. Individual patient information and county-level information about socioeconomic factors were combined for this analysis. After linking the data sets, we excluded counties with an

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Table 1. Distribution of average income and urban status of counties in the United States

	Whites	Blacks
Average per capita income of county of residence *$*		
0 to <10,000	0.9	28.7
10,000 to <15,000	21.1	44.4
15,000 to <20,000	55.4	19.1
20,000 to <25,000	19.6	5.2
≥25,000	3.0	2.6
Urban fraction of county of residence		
0–0.5	68	
0.5–1	32	

Entries are % of counties in United States based on evaluable total of 2918 for whites and 2859 for blacks. Income data is race-specific whereas urban fraction is not.

Table 2. Distribution of incident cases of t-ESRD in United States from 1983 to 1988 according to race, sex, age and characteristics of county of residence

	Whites	Blacks
Number *% of total*	49,781 (62%)	30,391 (38%)
% Male	58.0	55.8
Age group *% of race-specific total*		
0 to <20 years	5.7	4.2
20 to <40 years	35.2	33.0
40 to <60 years	59.1	62.8
Average per capita income of county of residence *% of race-specific total*		
0 to <10,000	0.1	9.7
10,000 to <15,000	5.0	55.5
15,000 to <20,000	32.1	28.8
20,000 to <25,000	46.2	5.2
≥25,000	16.6	0.8
Urban fraction of county of residence		
0–0.5	22.1	14.6
0.5–1	77.9	85.4

Entries are race-specific percentages.

average per capita income of $0 or with missing data for any variable.

The incidence rate of t-ESRD was modeled as a log-linear function of demographic and socioeconomic factors based on the Poisson distribution for infrequent events using SAS (SAS Institute, Cary, North Carolina, USA). The initial model incorporated variables known to be associated with t-ESRD (age, race, and sex) as well as average per capita county income, used as a surrogate measure of socioeconomic status. The county urban fraction was added as a surrogate marker of access to ESRD treatment, which is more abundant in urban settings. The nine geographic regions of the Census Bureau were included in the model as dummy variables to account for regional variations in the adjusted incidence of t-ESRD [1]. The analysis was confined to individuals younger than 60 years because it was felt that county-wide estimates of socioeconomic status would be most representative of this group. Age was categorized into the ranges of 0 to <20, 20 to <40, and 40 to <60 years to detect curvilinear relationships and to conform to the age categories used for the Census reports. Similarly, income was categorized into ranges of 0 to <10,000, 10,000 to <15,000, 15,000 to <20,000, 20,000 to <25,000, and ≥25,000 dollars per year. An overall model revealed a significant interaction between race and income using the likelihood ratio test [13] ($P = 0.0001$); separate analyses were therefore done for Blacks and Whites. There was evidence of overdispersion (by a factor of 2.48 for Blacks and 1.13 for Whites) based on the Pearson chi-square divided by its degrees of freedom [13]. Therefore, the standard errors for each model were adjusted by the square root of the corresponding overdispersion factor. Coefficient estimates were used to estimate the relative risk of t-ESRD compared to a reference category for each variable of interest. Factors were considered significant predictors of t-ESRD if the Wald χ^2, based on the adjusted standard error, yielded a P value <0.05.

Results

Table 1 shows the distribution of counties by income level and urban status. The average county per capita income was lower for Blacks than Whites. Relatively few Whites lived in counties with an average income below $10,000 and relatively few Blacks lived in counties with an average income above $25,000. Two-thirds of counties were predominantly rural as indicated by an urban fraction below 0.5.

Table 2 describes the study population of newly treated ESRD patients between the ages of 0 and 60 years from 1983 to 1988. Blacks comprised 38% of t-ESRD patients. The majority of patients were male. ESRD was much more common in the older age groups for both races. The average race-specific, per capita income of the county of residence was higher for Whites than Blacks. The vast majority of t-ESRD patients lived in counties with an urban fraction above 0.5; Black t-ESRD patients were even more likely to live in urban counties than White t-ESRD patients.

ESRD incidence was modeled as a function of individual demographic and county-wide socioeconomic factors for Whites (Table 3) and Blacks (Table 4). The reference rate for Blacks ($483.6/10^6$) was approximately fourfold higher than for Whites ($134.3/10^6$). In addition to the covariates shown in Tables 3 and 4, the models included the nine major geographic Census regions of the country. The adjusted incidence of t-ESRD varied significantly by region for both whites and blacks after adjustment for other covariates ($P < 0.001$ by likelihood ratio test for Whites and Blacks). For Whites, the relative risk of t-ESRD varied from 1.0 in New England (reference) to 1.22 in the East-North Central region. Greater geographic variation was found for Blacks with the relative risk ranging from 1.0 in the Pacific region (reference) to 1.34 in the West-North Central region. Geographic variability has been described previously although the explanation for the effect is unknown [1–5]. The geographic covariates were included to improve the precision of the models although all results were similar without adjustment for geographic region (not shown).

A significant, direct association was found between the adjusted incidence of t-ESRD and both males and older age. Compared to the 40- to 60-year-old reference group, the relative risk of t-ESRD was only 2 to 7% for the 0 to <20 year age group and 16 to 36% for the 20 to <40 year group (Tables 3 and 4). The relative risk of t-ESRD increased with age more sharply in

Table 3. Poisson regression model of t-ESRD incidence for Whites[a]

Covariate	Relative risk Male	Relative risk Female
Age[b]		
0 to <20 years	0.07 (0.063, 0.071)	0.06 (0.049, 0.056)
20 to <40 years	0.36 (0.354, 0.373)	0.25 (0.248, 0.263)
40 to <60 years	1.00 (reference)	0.71 (0.690, 0.725)
Urban fraction (100% urban vs. 100% rural)	1.21 (1.16, 1.26)	
Income $		
0 to <10,000	1.21 (0.94, 1.56)	
10,000 to <15,000	1.11 (1.06, 1.16)	
15,000 to <20,000	1.00 (reference)	
20,000 to <25,000	0.89 (0.87, 0.92)	
≥25,000	0.77 (0.75, 0.80)	

[a] Model includes the nine geographic census regions (relative risks shown in Fig. 1). The 95% confidence interval for the relative risk is shown in parentheses. Reference incidence rate (for 40- to 60-year-old men living in rural county with average per capita, county income of $15,000 to 20,000) was $134.3/10^6$. This rate should be multiplied by relative risk(s) of covariates to find a group-specific rate.

[b] Sex- and age-specific relative risks shown because of significant sex-by-age interaction ($P < 0.0001$)

Table 4. Poisson regression model of t-ESRD incidence for Blacks[a]

Covariate	Relative risk Male	Relative risk Female
Age[b]		
0 to <20 years	0.03 (0.026, 0.033)	0.02 (0.021, 0.027)
20 to <40 years	0.29 (0.278, 0.308)	0.16 (0.155, 0.174)
40 to <60 years	1.0 (reference)	0.74 (0.708, 0.774)
Urban fraction (100% urban vs. 100% rural)	0.94 (0.87, 1.03)	
Income $		
0 to <10,000	1.10 (1.01, 1.20)	
10,000 to <15,000	1.20 (1.14, 1.26)	
15,000 to <20,000	1.00 (reference)	
20,000 to <25,000	0.81 (0.75, 0.89)	
≥25,000	0.69 (0.57, 0.84)	

[a] Model includes the nine geographic census regions. The 95% confidence interval for the relative risk is shown in parentheses. Reference incidence rate (for 40- to 60-year-old men living in rural county with average per capita, county income of $15,000 to 20,000) was $483.3/10^6$. This rate should be multiplied by relative risk(s) of covariates to find a group-specific rate.

[b] Sex- and age-specific relative risks shown because of significant sex-by-age interaction ($P < 0.0001$)

males than females (Table 3 and 4), illustrating an interaction between sex and age.

The adjusted incidence of t-ESRD was significantly and directly associated with the fraction of the county population living in an urban area (urban fraction) for Whites (Table 3). This relationship could be due to increased treatment of ESRD or increased kidney disease in urban areas. The incidence of t-ESRD was not significantly associated with urban fraction in Blacks (Table 4).

The adjusted incidence of t-ESRD was significantly associated with average per capita income of the county of residence. For Whites, an inverse, linear relationship was found between

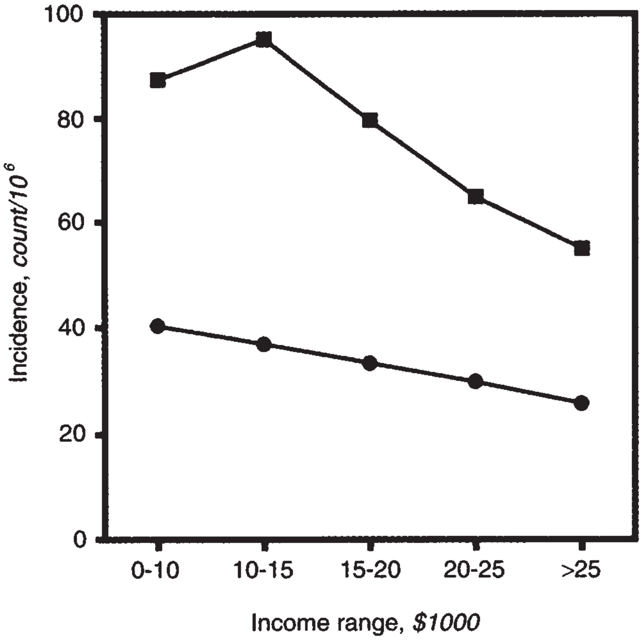

Fig. 1. *Estimated average incidence of t-ESRD rate for Whites (circles) and Blacks (squares) at different levels of income, adjusted for age and sex.*

t-ESRD and income level (Table 3, Fig. 1). This basic relationship was observed when income was modeled as either a categorical or a continuous variable. Whites were under-represented in the lowest county income category (0 to $10,000; Table 2), perhaps explaining the lack of significance for this coefficient in the categorical variable model (Table 3).

The adjusted incidence of t-ESRD was markedly higher for Blacks than Whites (Fig. 1). There was a significant, inverse relationship between t-ESRD incidence and income, although a categorical model indicated that the relationship might be positive at the lowest income levels (Fig. 1, Table 4). A similar relationship was found when income was entered into the model as a second degree polynomial rather than categories. For each race, t-ESRD incidence was associated with income independently of the model covariates (age, sex, urban fraction and geographic region).

The degree to which socioeconomic status could explain racial differences in t-ESRD incidence was evaluated using the overall model for White and Black cases. Without adjustment for per capita county income, the relative risk for t-ESRD for Blacks compared to Whites was 3.78 ($P < 0.0001$). After adjustment for income, the relative risk was 3.38 for Blacks compared to Whites ($P < 0.001$) at the mean income level. The relative risk of t-ESRD for Blacks relative to Whites declined as a function of average per capita county income (Fig. 2). Differences in socioeconomic status appear to explain some but not most of the difference between Blacks and Whites in the incidence of t-ESRD.

Discussion

In agreement with previous reports from USRDS and other sources, we found that the incidence of t-ESRD is positively associated with increasing age, male sex, and Black race [1, 14].

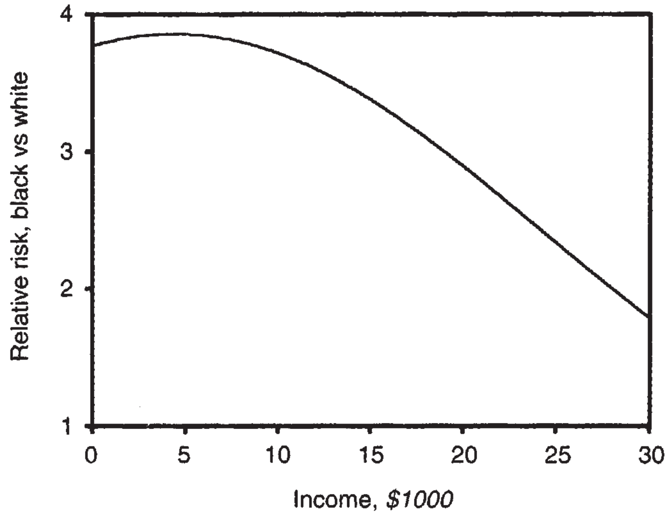

Fig. 2. *Relative risk of t-ESRD for Blacks relative to Whites at different levels of average race-specific, per capita county income.*

The age effect may in part relate to the natural history of diseases such as diabetes and hypertension that gradually lead to renal injury over time. Also, the incidence of t-ESRD is growing most rapidly among older age groups [1], perhaps due to increased patient acceptance into treatment and to the effectiveness of modern treatments that prevent competing cardiovascular mortality or delay the progression of severe kidney disease. The sex effect may reflect worse hypertension and end-organ damage in men compared to women. The race effect represents a long recognized but growing problem with probable genetic, environmental, and social dimensions [15]. The aim of our study was to determine if t-ESRD incidence was related to socioeconomic status and if differences in socioeconomic status could partially explain the increased incidence of t-ESRD among Blacks.

To approach this question, we used the race-specific, average per capita income of the county of residence as a surrogate for the socioeconomic status of individual patients. Patients older than 60 years of age were excluded because of the variability in referral and acceptance practices for older individuals and the questionable applicability of county income averages to retirees. The addition of average income to race-specific Poisson models of t-ESRD incidence improved the predictive power over simpler models. Thus, differences in socioeconomic status appear to explain some of the variability in t-ESRD incidence above and beyond the contribution of age, race, and sex.

In general, the incidence of t-ESRD declined as average income rose (Fig. 1). Although causality cannot be assumed in an ecological study, one may speculate that the observed relationship could be explained if higher income levels were associated with better preventive medical care, lower exposure to environmental nephrotoxins, or a greater rate of refusal of dialysis treatment by ESRD patients. Access to ESRD care does not appear to be limited by poverty because the incidence of t-ESRD treatment is higher at lower income levels.

A possible exception to the predominant relationship found between t-ESRD incidence and income is an apparent drop in the incidence of t-ESRD among Blacks at the lowest income level (Fig. 1, Table 4). Several explanations are plausible. Extreme poverty (that is, income <$10,000/year) may be a barrier to ESRD treatment. Although Medicare covers most dialysis costs, the uncovered and indirect costs (such as transportation, and initial entry into the health care system before ESRD) may constitute a prohibitive obstacle to treatment for some Black individuals in the lowest socioeconomic group. Alternatively, the lower than expected incidence of t-ESRD may represent the effect of Medicaid coverage for individuals of extremely limited means. It is possible that the very poor receive better preventive health than slightly more affluent individuals with incomes that exceed the eligibility threshold for Medicaid. Also, Medicaid may fund dialysis treatment for some poor individuals; incident cases funded by Medicaid rather than Medicare may not be included in the USRDS database. Based on our data, it is uncertain if the lower than expected incidence of t-ESRD for Blacks in the lowest income category represents a deficiency or success of the health care system or simple under reporting; further research is needed in this area.

The incidence of t-ESRD remained significantly higher for Blacks than Whites with adjustments for socioeconomic status as well as age, sex, urban status, and geographic region (Fig. 2). Thus, the higher incidence of t-ESRD that has been consistently found in Blacks [14] cannot be fully explained by their lower average socioeconomic status.

A relationship between t-ESRD and socioeconomic status has been described in several preliminary reports. Rostand noted a strong, direct correlation between the number of patients with t-ESRD and the number of households with incomes less than $7,500 within individual zip codes in Jefferson County, Alabama [16]. In a case-control study of new t-ESRD patients, the risk of t-ESRD was inversely related to annual income and years of schooling [17]. The income measurement was not described but it is important to realize that individual income may fall because of renal failure. Nonetheless, these investigators also found that the effect of socioeconomic status did not explain racial differences in the incidence of t-ESRD. A mapping study of t-ESRD at the state level found that the adjusted incidence rate was positively associated with the fraction of the state population living in a metropolitan area and with per capita gasoline consumption [3]. The former association agrees with our finding that t-ESRD was directly related to urban fraction among Whites (Table 3). Patterns of t-ESRD incidence have also been mapped at the county level [4, 5]. Although reasons for county variability are incompletely understood, socioeconomic factors have been hypothesized to explain some of the variation. Survival of t-ESRD patients was also found to be positively associated with income [18].

Socioeconomic status could influence renal disease through an effect on blood pressure or diabetes. Hypertension is the second most common attributed cause of t-ESRD [1] and high blood pressure accelerates the progression of kidney disease from other causes [19]. Previous studies have shown that the level of blood pressure and the prevalence of hypertension are inversely related to socioeconomic factors such as income, educational level, and presence of health insurance [6–8]. Therefore, blood pressure may be an important link between socioeconomic status and the incidence of t-ESRD.

Diabetes is the most commonly attributed cause of t-ESRD in the United States [1]. There is an inconsistent relationship between type I diabetes (insulin dependent, juvenile-onset) and socioeconomic status [9]. In contrast, the risk for type II diabetes (adult-onset or non-insulin dependent) is inversely associated with socioeconomic status [10]. Because type II diabetes is the predominant cause of diabetic nephropathy, it is possible that diabetes is an additional link in the observed association between t-ESRD and income.

The incidence of t-ESRD in Whites was directly associated with the urban fraction of the county of residence. Adjustment for this factor strengthened the association of t-ESRD with income. An explanation for this finding could be that patients with advanced renal disease are more likely to receive dialysis care in an urban setting than in a medically isolated rural community. Another possibility is that environmental nephrotoxins are more abundant in urban areas, leading to more kidney disease. The incidence of t-ESRD was not associated with urban fraction in Blacks, perhaps because there is less variation in the urban fraction of communities where most Blacks live (Table 2).

In summary, we have found an inverse association between the incidence of treated ESRD and socioeconomic status, as estimated by average income of the county of residence, after adjustment for race, sex, and age. This relationship may be mediated by blood pressure, diabetes, and urban environmental characteristics. The findings have implications for predicting and modifying future trends in t-ESRD incidence.

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